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W. B. BIZZELL, President

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DIVISION OF CHEMISTRY

ORGANIC CONSTITUENTS OF THE SOIL

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ORGANIC CONSTITUENTS OF THE SOIL

BY

G. S. FRAPS

The organic matter of the soil consists of the residues of plants and animals, animal excrements, and the products of the action of bacteria, yeasts, molds, and other soil organisms. All the compounds which are found in plants or animals enter the soil, though the presence of some of them is very transitory. Sugars, urea, and similar substances are rapidly changed into other bodies. Cellulose and lignin, which make up the woody matter of plants, decay much more slowly, and remain in the soil for some time. Lactic, acetic, and butyric acids are produced by the fermentation of sugars and starches. Vegetable acids are introduced into the soil in plant residues, but are quickly destroyed by bacteria. Proteins and fats persist for a longer or shorter time, according to their nature, nuclein being apparently quite resistant. It is thus possible for all the organic compounds in plants or animal residues to be present, in greater or less quantity, in the soil, and the student of soil chemistry must bear this possibility in mind. (Fraps: Principles of Agricultural Chemistry, page 157.)

ORGANIC CARBON OF THE SOIL

A study was made of the organic carbon of the soil. The total carbon was determined by combustion with sulphuric acid and potassium bichromate, as described by Cameron of the Bureau of Soils. Inorganic carbon in the form of carbonate was determined in another sample, and deducted.

The ratio of the carbon to nitrogen was found by dividing the percentage of organic carbon by the percentage of nitrogen. The relations are discussed on the basis of averages.

Relation of Surface Soils to Subsoil. Table 1 shows the average relation of surface soils to subsoils as regards organic carbon. The surface soils contain about 50 per cent. more organic carbon, and 50 per cent. more of nitrogen. The ratio of carbon to nitrogen was a little wider for the surface soils than for the subsoils, being 9.2 for surface soils, and 8.3 for subsoils. The difference is not great, but there is on an average a little more carbon in proportion to nitrogen in the organic matter of surface soils. The surface soils also vary more in the ratio of carbon to nitrogen.

Table 1. Relation of surface soils to subsoils in organic carbon.

	Surface soil	Subsoils
Organic carbon, per cent	0.65	0.44
Ratio carbon to nitrogen	9.2	8.3
Nitrogen, per cent	0.074	0.051
Variation in ratio, carbon to nitrogen	2–39	4–18
Number averaged	76	35

Relation of Organic Carbon to Percentage of Nitrogen. Table 2 contains the average for the soils divided in groups according to the percentage of nitrogen contained. As the average per cent. of nitrogen increases, the average per cent. of organic carbon in the soil increases, but the ratio of carbon to nitrogen does not vary to any great extent.

Table 2. Relation of organic carbon to percentages of nitrogen.

Group of soils	Organic carbon	C/N ratio	Per cent nitrogen	Surface soils	Number averaged
0–.020 per cent nitrogen	.14	7	.020	3	5
.021–040 per cent nitrogen	.30	10	.032	24	35
.041–080 per cent nitrogen	.51	9	.057	19	33
.081–120 per cent nitrogen	.88	9	.099	22	27
Over 0.12 per cent nitrogen	1.18	7	.163	9	9

Relation of Carbon-Nitrogen Ratio to Composition. Table 3 contains the composition of the soils arranged and averaged according to the carbon-nitrogen ratio. As the carbon-nitrogen ratio increases, the percentage of organic carbon in the soil increases. The percentage of nitrogen is smallest with the soils having a carbon-nitrogen ratio over 10 and next with the soils having a carbon-nitrogen ratio less than 5.

Table 3. Relation of carbon-nitrogen ratio to composition of soil.

Group	Organic carbon in soil per cent	C/N ratio	Per cent nitrogen	No. of surface soils	Total number of soils
C/N Ratio less than 5	.25	4	.061	7	13
C/N Ratio 5.1–7	.50	7	.075	17	29
C/N Ratio 7.1–10	.65	9	.071	36	43
C/N Ratio over 10	.72	14	.052	15	24

General Discussion. The determination of organic carbon in the soil throws little light upon the quality of the soil and it hardly seems necessary to go to the trouble of determining it in ordinary soil analyses. With most soils, the percentage of organic carbon can be judged from the percentage of nitrogen present. Ordinarily 9 parts of carbon will be associated with 1 part of nitrogen in Texas soils. We could also assume that 1 part of nitrogen is equal to 16 parts of organic matter in the soil, for it is possible that the organic matter of the soil contains about 55 per cent. of the carbon. (Fraps' Principles of Agricultural Chemistry, page 162.) The carbon-nitrogen ratio will vary with different soils, and the percentage of carbon in the organic matter of different soils will also vary, but at the present stage of our knowledge, the estimation of the organic carbon of the soil gives little information of significance and the estimation of organic carbon need not be made until further investigation shows that such work would serve a useful purpose.

PENTOSANS IN THE SOIL

The presence of pentosans in soil was demonstrated by De Chalmot and others (Am. Chem. Jour., 1894, p. 229), and confirmed by Shreiner and Shorey, who found that in ten soil samples, pentosan carbon made up 1.30 to 28.5 per cent. of the total carbon.

Method of Work. Pentosans were run in a number of soils for the purpose of ascertaining if there were any relation between the quantity of pentosans, and other soil constituents. For this purpose, 50 grams soil were distilled with hydrochloric acid in the usual way, and pentosans determined by the Methods of the Association of Official Agricultural Chemists.

Relation to Nitrogen Content of Soil. The soils were divided into groups according to their nitrogen content, and averaged. The results of these averages are given in Table 4. This table gives the number of samples averaged, the average percentage of nitrogen of the soil, the percentage of pentosans in the soil, and the ratio secured by dividing the percentage of pentosans by the percentage of nitrogen, expressed as per cent.

Table 4. Relation of pentosans to nitrogen content of soils.

Group	Number of samples	Per cent nitrogen	Per cent pentosans	Pn/N ratio
0–.04 per cent nitrogen	65	.030	.022	.72
.041–.08 per cent nitrogen	95	.057	.042	.74
.081–.12 per cent nitrogen	44	.103	.077	.75
Over .12	53	.161	.131	.79

The table shows that the average percentage of pentosans increases with the average nitrogen content of the soil. The ratio of pentosans to nitrogen increases slightly with the average nitrogen content of the soil, but the average ratio is fairly constant, considering the small amount handled.

Relations of Pentosans of Surface Soils and Subsoils. The soils were divided into two groups, surface soil and subsoils, and the analyses averaged. The results are given in Table 5. The pentosan-nitrogen ratio for the surface soils is 77 per cent. and for the subsoils, 70 per cent. The surface soils therefore contain about 10 per cent. more pentosans in proportion to the nitrogen than the subsoils, but this is a comparatively small difference.

Table 5. Comparison of pentosans of surface soils and with those of subsoils.

	Surface soil	Subsoil
Average nitrogen	.092	.062
Average pentosans	.075	.045
Average Pn/N ratio	.77	.70
Number averaged	145	111

Relation to Composition. Table 6 contains the average composition of the soils arranged in groups according to the pentosan-nitrogen ratio. With the first group, the pentosan-nitrogen ratio is less than 40 per cent. and these soils therefore contain an excess of nitrogen to pentosans. In the second group, the ratio is 1:.40 to 1:.80, with the third group the ratio is 1:.801 to 1:1.20, and with the last group, the ratio is over 1:1.201. This last group therefore contains soils with the highest proportion of pentosans compared to the nitrogen.

Table 6. Average composition of soils arranged by pentosan-nitrogen ratio.

	Per cent nitrogen	Per cent pentosans	Pn/N ratio	Per cent lime	Act. P_2O_5	Act. K_2O	Ac. Consd.	Number surface soils	Total number soils
Ratio below .40– average	.076	.04	.31	1.78	51.9	173.8	20.7	12	36
Ratio .40.1–.80.– average	.073	.05	.60	26.90	91.5	230.0	32.9	65	123
Ratio .80.1–1.20– average	.084	.08	.97	3.17	76.2	201.5	28.2	57	77
Ratio over 1.20.1– average	.077	.11	1.48	1.19	66.5	206.4	16.9	9	22

The percentage of nitrogen in the soils is very nearly constant. The percentage of pentosans in the soils increases from .04 to .11. In other words, the increase in the proportion of pentosans to nitrogen is accompanied by an increase in the pentosans in the soil and not by an increase in the nitrogen. The pentosan-nitrogen ratio increases, since the soils were arranged in this way. The per cent. of lime, parts per million active phosphoric acid, and parts per million of active potash in the groups, afford no information.

The first group contains 12 surface soils and 24 subsoils, a total of 36. In the second group there are 65 surface soils and 48 subsoils, and in the groups having a pentosan-nitrogen ratio of 1:.801-1.20, the number of surface soils is 57 and of subsoils 20. The number of surface soils in the last group is 9, and subsoils 13. The proportion of subsoils is therefore highest in the extremes and the proportion of surface soils is high in the means. There is thus observed a tendency for the subsoils to vary more than the surface soils,—the same tendency that we observed with respect to nitrification.

No relation could be observed between locality from which the soils were taken and the percentages of pentosans present.

OXIDATION OF PENTOSANS IN SOILS

In order to study the oxidation of pentosans in the soil, 20 grams of raw material were mixed with 500 grams of soil; water was then added to one-third the water capacity and mixed thoroughly, and the mixture placed in jars. Pentosans were determined on the original mixture, and on jars taken after one week, two weeks, and eight weeks. Water was added to replace that lost by evaporation.

Table 7. Percentages of pentosans in soil mixtures after various intervals.

	Addition	Original	1 week	2 weeks	4 weeks	8 weeks	Originally added	From addition after 8 weeks	Percentage not oxidized after 8 weeks
1956	None	.02	.02	.02	.02	.02	....	....	....
	Cottonseed meal	.30	.14	.09	.08	.04	.28	.02	7
	Rice bran	.38	.30	.30	.25	.24	.36	.22	61
	Alfalfa hay	.59	.57	.41	.22	.20	.57	.18	31
	Excrement	.38	.37	.32	.31	.29	.36	.27	75
	Sudan grass hay	.74	.63	.55	.45	.27	.72	.25	34

The result of one of these experiments is shown in Table 7. The pentosans in cottonseed meal disappeared rapidly during the first week. They disappeared less rapidly with the other materials. At the end of eight weeks, 7 per cent. of the pentosans in cottonseed meal remained in the soil, 31 per cent. of those in Sudan grass hay, 61 per cent. of those in rice bran, and 75 per cent. of those in sheep excrement. It is seen that there is a difference in the rate of disappearance of pentosans in the different materials. As might be expected, those in the excrement are the most resistant to the action of the soil bacteria.

Other experiments were made, but the results were similar to this one.

SUGARS BY HYDROLYSIS OF SOILS

The reducing sugars formed by heating 100 grams soil in a boiling-water bath with 200 c.c. of 1¼ per cent. sulphuric acid for 30 minutes, followed by heating the neutralized filtrate with 20 c.c. hydrochloric acid to 200 c.c. for 3 hours, was determined by Allihn's method. See Table 8. The amount of reducing substance calculated as dextrose produced in this way varied from .002 to .215 per cent. with an average of .058 for 77 soils. The average amount of nitrogen was .134, and the sugar-nitrogen ratio was 0.43. This may be compared with the pentosan-nitrogen ratio of about .74. The reducing substances calculated to dextrose are thus about 60 per cent. of the pentosans.

Table 8. Relation of reducing substances (sugars) formed by hydrolysis to nitrogen of soil.

Number of soils	77
Percentage sugars	.058
Percentage nitrogen	.134
Sugar-nitrogen ratio	.43

The sugars produced may come from cellulose, pentosans, or similar material from which sugars can be formed by boiling with 1¼ per cent. sulphuric acid.

PERMANGANATE-INSOLUBLE NITROGEN

The nitrogen-insoluble in neutral potassium permanganate was determined in a number of soils. Fourteen grams of soil were digested with 125 c.c. of a solution of 16 grams of potassium permanganate in 1000 c.c. water for 30 minutes in a steam bath, and nitrogen determined in the residue after filtration and washing.

Table 9. Relation of permanganate—insoluble nitrogen to total nitrogen content of soils.

	Per cent nitrogen	Per cent Perman. Insol.	Number of soils
Group 1 .041–.06 per cent nitrogen	.053	37	2
Group 2 .061–.08 per cent nitrogen	.073	40	4
Group 3 .081–.10 per cent nitrogen	.092	34	26
Group 4 .101–.12 per cent nitrogen	.112	37	27
Group 5 .121–.14 per cent nitrogen	.130	36	28
Group 6 .141–.16 per cent nitrogen	.151	31	12
Group 7 .161–.18 per cent nitrogen	.171	43	6
Group 8 .181–.20 per cent nitrogen	.193	33	7
Group 9 .221 up per cent nitrogen	.243	26	9

This determination was made in a number of soils, and the results studied from various angles. As could be expected, the nitrogen in soils was largely insoluble in potassium permanganate. Table 9 shows some of the relations which were examined. Study of the results from various angles shows no significance, and especially no relation could be traced between the soluble and insoluble nitrogen and the results of pot experiments in which nitrogen was omitted. See Table 10. Further details of this work seem unnecessary.

Table 10. Permanganate-insoluble nitrogen averaged by groups.

Group insoluble nitrogen	Number in group	Perman. insoluble nitrogen per cent	Per cent nitrogen	Active phosphoric acid	Acid consumed	Lime per cent	1st crop, gm.		2nd crop, gm.		3rd crop, gm.	
							KP	KPN	KP	KPN	KP	KPN
0–20%	7	16.1	.126	64.9	58.7	12.46	13.9	16.8	17.3	26.4	.....	2.7
20.1–30%	30	25.8	.136	123.5	21.1	1.68	14.6	20.8	9.9	19.2	7.7	21.8
30.1–40%	43	34.5	.122	103.2	31.2	2.40	13.6	16.6	7.9	19.8	5.4	21.1
40.1–60%	25	45.6	.125	151.0	27.1	1.65	15.9	27.1	10.2	17.9	9.0	22.8
Over 60.1%	6	65.1	.115	167.6	30.0	3.90	20.2	26.2	.7	1.4	.....	.....

NITROGEN COMPOUNDS DISSOLVED IN SALT WATER

The nitrogen dissolved from 70 grams of soil in twenty-four hours by 250 c.c. of 10 per cent. common salt was determined in the filtrate. On an average of 43 soils containing .146 per cent. nitrogen, .005 per cent. nitrogen was dissolved by the salt water. This is about 4 per cent. of the total nitrogen of the soil. The soils used for these tests were mostly high in nitrogen. With the exception of one or two soils which contain unusually high percentages of nitrogen soluble in salt water, the results seem to be of little significance.

NITROGEN DISSOLVED BY CAUSTIC POTASH

The nitrogen dissolved from 70 grams of soil in twenty-four hours at room temperature by 250 c.c. of tenth-normal potassium hydroxide was determined in 21 soils. The average quantity of nitrogen in the soils is .147 per cent. and the average amount of nitrogen dissolved was .0149. On an average 10 per cent. of the nitrogen in the soil was dissolved by the potassium hydroxide. There were some variations in the amount of nitrogen dissolved from the different soils, and it might be desirable to study this matter further in connection with some of the pot experiments.

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SUMMARY AND CONCLUSIONS

The determination of organic carbon in the soil throws little light upon the quality of the soil and is hardly necessary for ordinary soil analysis.

The percentage of organic carbon can be judged from the percentage of nitrogen present.

The average percentage of pentosans increases with the average nitrogen content of the soil.

Surface soils contain slightly more pentosans in proportion to nitrogen than subsoils, but the difference is very small.

Pentosans in cottonseed meal disappeared rapidly from the soil during the first week, and at the end of eight weeks, 7 per cent. of the original pentosans were present from cottonseed meal, 31 per cent. from Sudan grass, 61 per cent. from rice bran, and 75 per cent. from sheep excrement.

The amount of reducing substance, calculated as sugars, produced by heating the soil with 1¼ per cent. sulphuric acid varied from .002 to .215 per cent. with the average of .058 for 77 soils.

The nitrogen insoluble in permanganate was studied, but no relation could be found between the soluble and insoluble nitrogen and the results of pot experiments with nitrogen on soils.

Salt water, 10 per cent., dissolved .005 per cent. nitrogen on an average from 43 soils averaging .146 total nitrogen. The results seem of little significance.

On an average, 10 per cent. of the nitrogen of the soil was dissolved by N/10 potassium hydroxide from 21 soils.